Deep Learning-Based Autoencoder for Data-Driven Modeling of the European XFEL Photoinjector

LEAPS Integrated Platform Workshop

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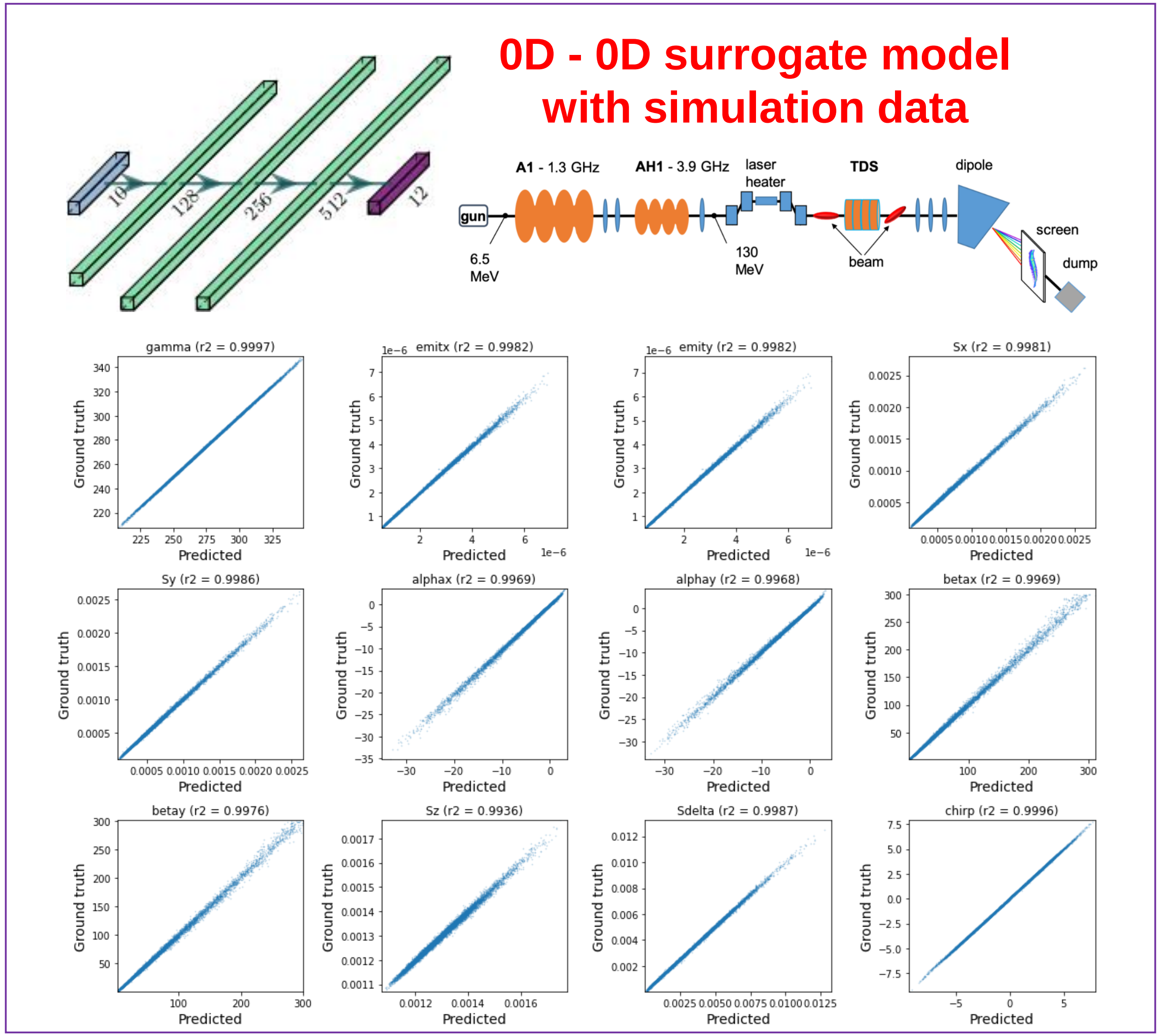
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Why experimental data-driven modeling?

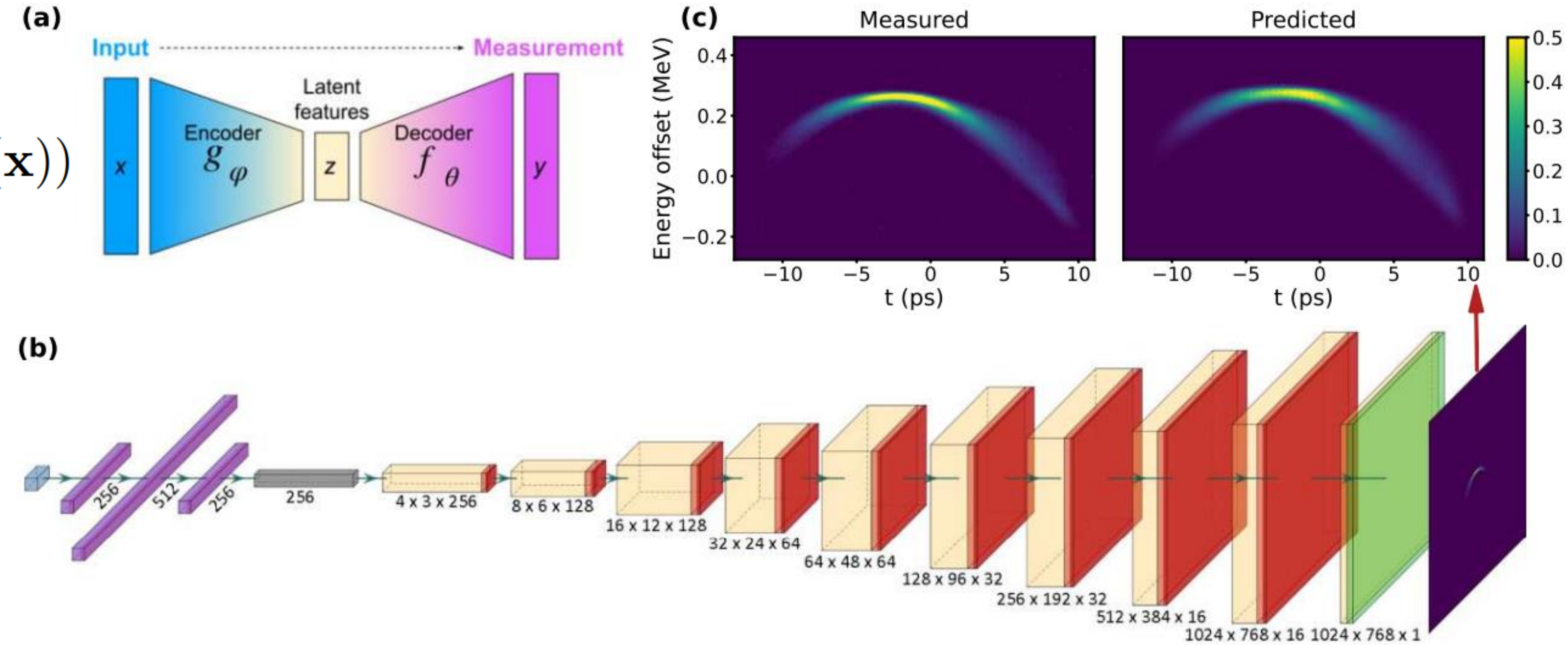


- Collective effects are simulated with different theoretical assumptions.
- **Electron emission process from a photocathode is highly simplified.**
- **Simulation does not take into account aging and imperfection of accelerator components.**
- High-resolution simulation can be prohibitively expensive.

Encoder-decoder structure

- Demonstrate neural networks can generate an **explicit mapping** between the input and the output **mega-pixel** images in **a continuous space** with reasonable computational resources and data.

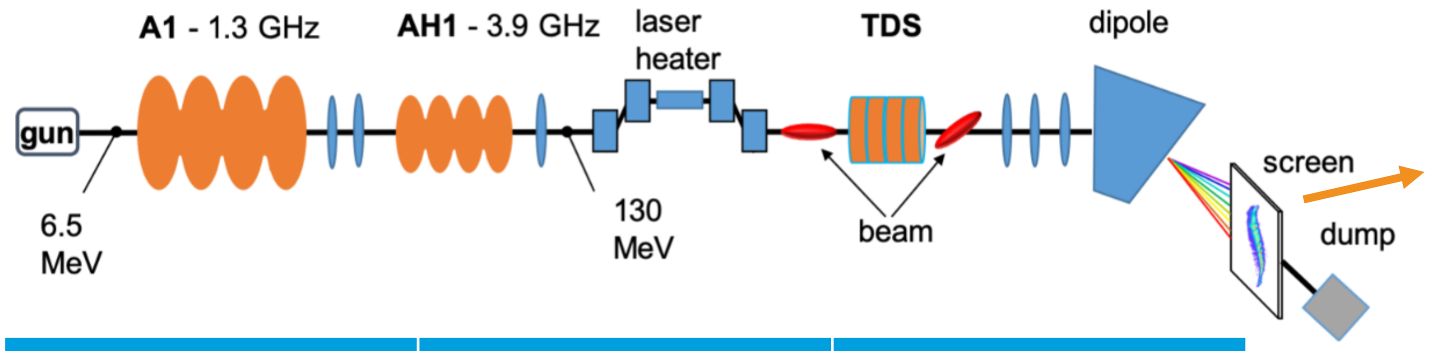
$$\min \ \mathcal{L}(\mathbf{y}, f_\theta(g_\varphi(\mathbf{x})))$$

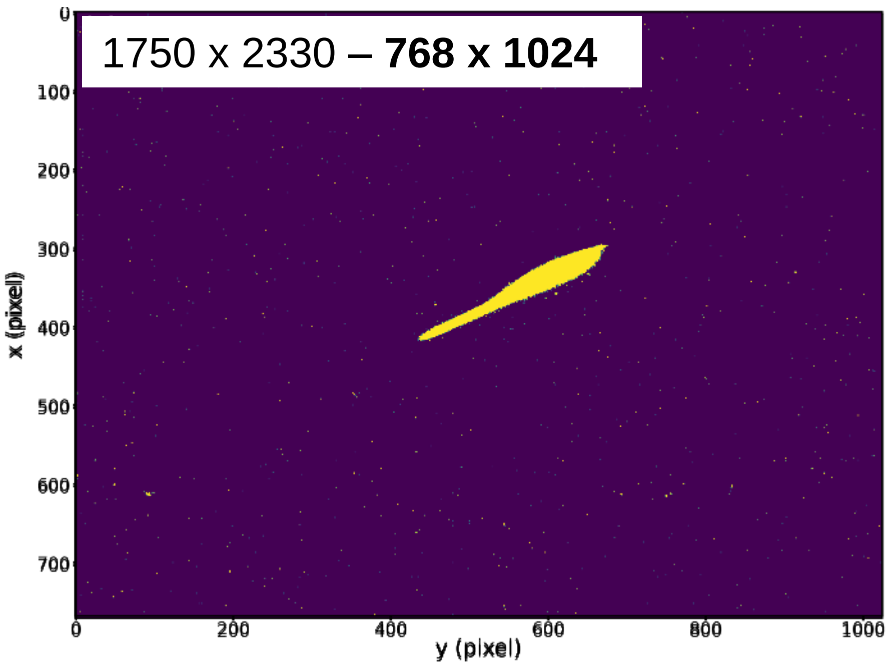


- Propose a way of building **scalable**, **explicable** and **maintainable** applications for a (sub) system.

J. Zhu, Y. Chen, F. Brinker, W. Decking, S. Tomin, H. Schlarb, arXiv:2101.10437

Data collection and processing



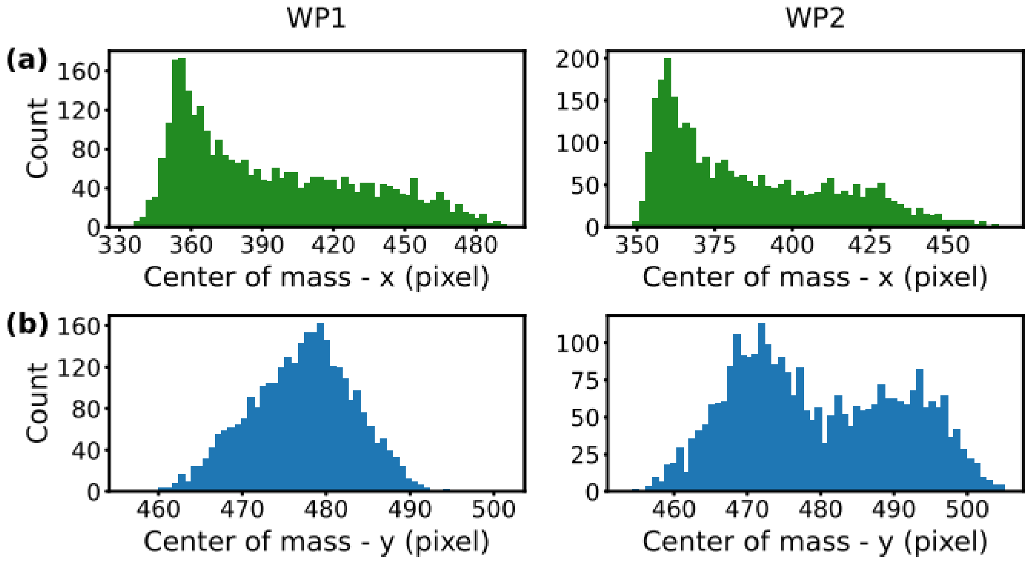


	WP1	WP2
Gun phase (deg)	-3 ~ 3	-3 ~ 3
A1 phase (deg)	-6 ~ 6	-6 ~ 6
AH1 phase (deg)	-6 ~ 6	\
AH1 gradient	…	0

- **3000 shots for each working point (80/20 split)**
- **With NVIDIA Tesla P100**

  Training: ~10 hours (not fully optimized),

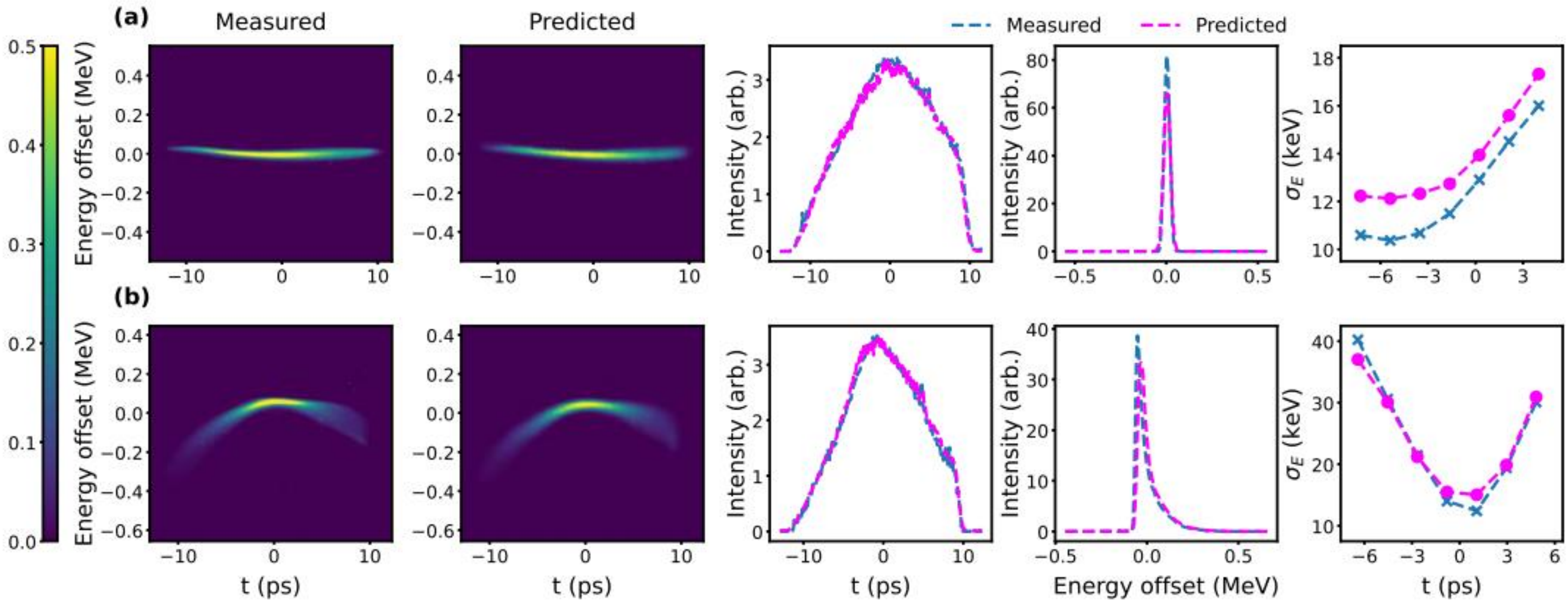
  Prediction (single image): ~ 20 ms



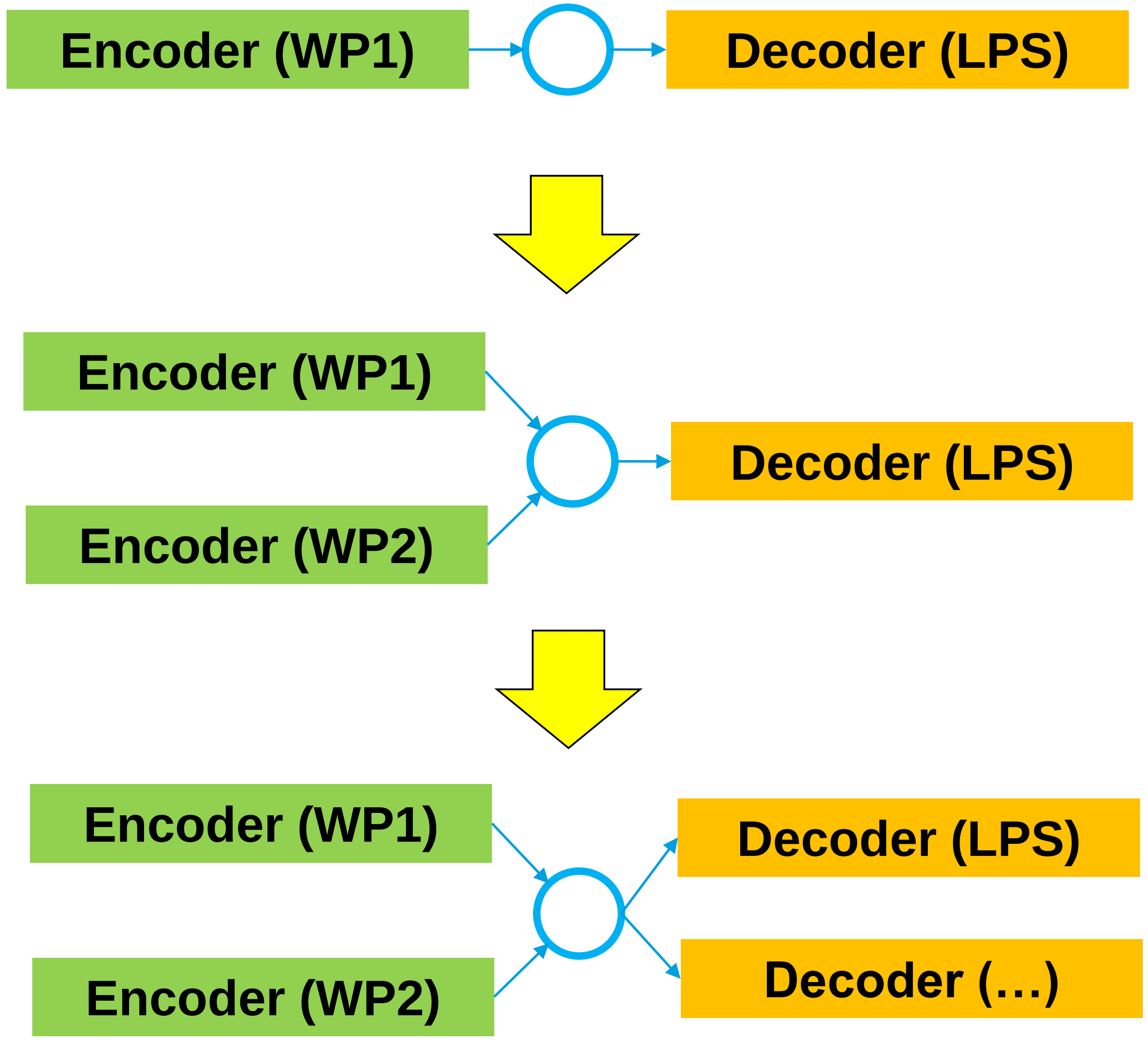
Prediction Quality

SSIM: ~0.995, MSE: ~3×10^{-5}

Current profile **Energy spectrum** **Energy spread**



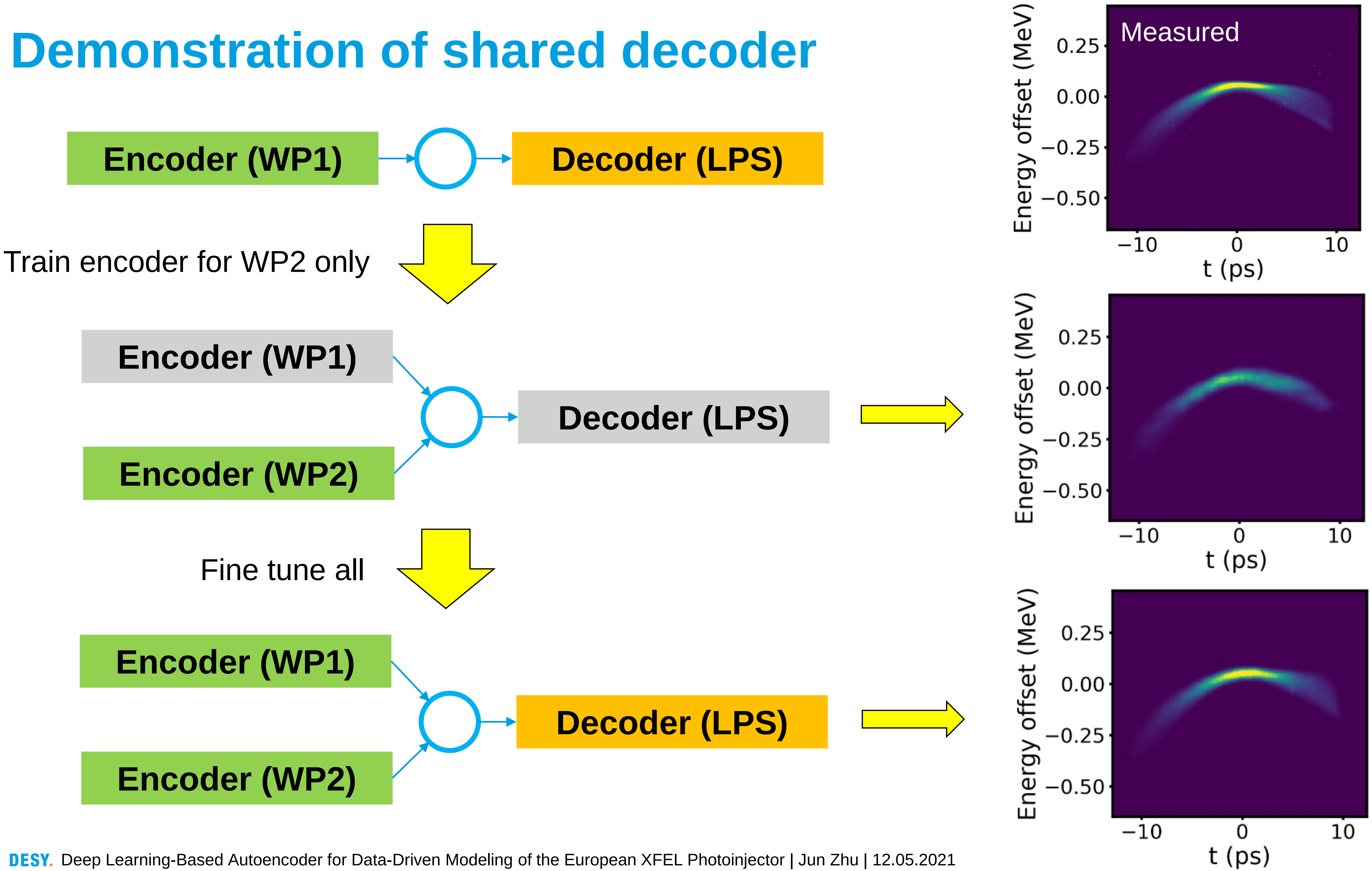
Explicability, Scalability and Maintainability



- Reduce the input parameter space.
- **Time interval between data collections of different working points can be long.**
- Number of input data and the type of input data can change over time.
- **Software engineering**

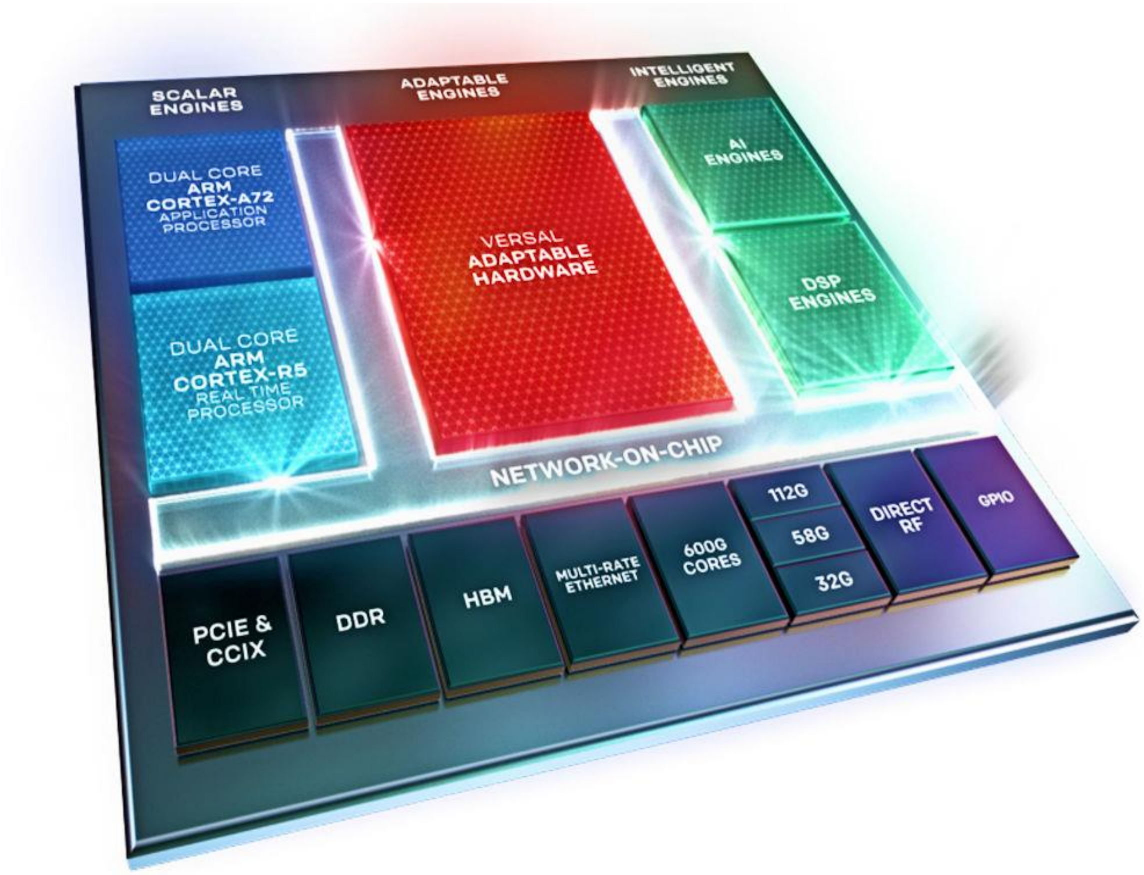
  Code vs Code + data + weights
- Benefits of multi-task learning.

Demonstration of shared decoder



Hardware acceleration

- High throughput and **extremely low latency** (e.g. intra-bunch feedback)



Collaboration with G. Fey, A. A. Zoubi, G. Martino from TUHH.

A preliminary benchmark study will be presented at **Intelligent Process Control Seminar** at DESY soon.

Summary

- Neural network trained only with experimental data can make high-fidelity predictions of mega-pixels images of electron beam profile.
- The encoder-decoder structure can possibly be applied to other (sub)system in a scientific facility. For example, a scientific instrument after the photon beamline.